

# CODE OF PRACTICE

**WORKS** (PROTECTIVE EARTHING, UNDERGROUND CABLE SYSTEMS  
AND MAINTENANCE OF SUPPORTING STRUCTURES FOR POWERLINES)  
ELECTRICAL SAFETY ACT 2002

ELECTRICAL SAFETY OFFICE

**CODE OF PRACTICE: WORKS**

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# 1. INTRODUCTION

## 1.1 Important Dates

This Code of Practice:

- \* Was made on 23 September 2002
- \* Commences on 1 October 2002
- \* Expires on 23 September 2007

## 1.2 What is a Code of Practice?

A Code of Practice is a document made under the *Electrical Safety Act 2002* (the Act). It gives practical advice on ways to discharge electrical safety obligations. Included in a Code are ways to identify and manage exposure to risks of injury and property damage caused, directly or indirectly, by electricity.

## 1.3 What is this Code about?

This Code gives practical advice on ways for an electricity entity to manage electrical safety risks associated with earthing systems, underground cable systems, and supporting structures for overhead lines forming parts of the works of an electricity entity.

## 1.4 What is an “Electricity Entity”?

Under the *Electrical Safety Act 2002*, **electricity entity** means:

- (a) a generation entity, transmission entity or distribution entity; or
- (b) a special approval holder that is authorised under the *Electricity Act 1994* to do something that a generation entity, transmission entity or distribution entity may do under that Act; or
- (c) Queensland Rail (ABN 47 564 947 264).

## 1.5 Obligations under the *Electrical Safety Act 2002*

The Act imposes obligations on electricity entity ensure that its works are:

- \* electrically safe; and
- \* operated in a way that is electrically safe.

This obligation includes the requirement that the electricity entity inspects, tests and maintains the works.

**Works** of an electricity entity means the electrical equipment, and electric line associated equipment, controlled or operated by the entity to generate, transform, transmit or supply electricity.

An example of works of an electricity entity is an overhead distribution system of a distribution entity, including transformers and switches. Examples of what is not works of an electricity entity are appliances or fixed wiring in an electricity entity's workshop or offices.

## 1.6 How can the entity meet its obligations?

Under the Act, there are three ways an entity can meet its electrical safety obligations – either through regulation, ministerial notices or codes of practice. Where applicable, the entity must comply in the following manner to meet its obligations:

- a. if a regulation is identified as prescribing a way of discharging an electrical safety obligation, the entity will fail to meet its obligation if it contravenes the regulation.
- b. if a ministerial notice prescribes a way of meeting an electrical safety obligation in relation to an electrical risk, the entity will fail to meet that obligation if it contravenes the ministerial notice.
- c. if a code of practice states a way of meeting its electrical safety obligation, the entity will fail to meet that obligation if it:
  - \* contravenes the code or act in a way inconsistent with the code; and
  - \* does not follow a way that is equally effective to, or more effective than, the code of practice for discharging the entity's electrical safety obligation.

An electricity entity should also refer to Section 4 of this code on risk management for meeting its obligations generally.

## **1.7 Requirements of the *Electrical Safety Regulations 2002***

### **Section 131 – Performance and other requirements for works.**

The following requirements apply for the works of an electricity entity –

- (a) the works must be able to perform under the service conditions and the physical environment in which the works operate;
- (b) the works must have enough thermal capacity to pass the electrical load for which they are designed, without reduction of electrical or mechanical properties to a level below that at which safe operational performance can be provided;
- (c) to the greatest practicable extent, the works must have enough capacity to pass short circuit currents to allow protective devices to operate correctly;
- (d) the works must have enough mechanical strength to withstand anticipated mechanical stresses caused by environmental, construction or electrical service conditions;
- (e) the works must be designed and constructed to restrict unauthorised access by a person to exposed live parts;
- (f) design, construction, operation and maintenance records necessary for the electrical safety of the works must be kept in an accessible form;
- (g) parts of the works whose identity or purpose is not obvious must be clearly identified by labels, and the labels must be updated as soon as possible after any change is made to the works;
- (h) electrical equipment intended to form part of the works of an electricity entity must undergo commissioning tests and inspection to verify that the electrical equipment is suitable for service and can be operated safely.

## **1.8 Defences for failing to meet an entity's electrical safety obligation**

If charged with a breach of obligation, an entity can provide a valid defence by establishing that the breach was due to causes beyond its control. In this instance, the entity cannot claim as a defence those sections of the Criminal Code relating to an accidental act or omission, or a mistaken belief.

Where there is no regulation, code of practice or ministerial notice that tells the entity how to meet its electrical safety obligation under the circumstances, the entity can seek to establish that it chose an appropriate way, took reasonable precautions and exercised proper diligence to discharge its safety obligation.

## **1.9 Penalty for failure to meet an electrical safety obligation**

A maximum penalty for failing to discharge an electrical safety obligation is:

- \* if the breach causes death or grievous bodily harm – 5x800 penalty units for the entity and 800 penalty units or two years' jail for any executive officer;
- \* if the breach causes bodily harm – 5x500 penalty units for the entity and 500 penalty units or one year's jail for any executive officer; or
- \* otherwise – 5x400 penalty units for the entity and 400 penalty units or 6 months' jail for any executive officer.

## 2. RISK MANAGEMENT

This Code of Practice should be used on the basis that appropriate workplace health and safety risk management processes are applied. This section examines the basics of such a process.

### 2.1 Hazards and risks

Hazards and risks are NOT the same thing. A hazard is something with the potential to cause harm. Included in this definition are substances, plant, work processes or other aspects of the work environment, or all of these factors. Risk is the likelihood that death, injury or illness might result from the hazard.

Consider, for example, an unearthed metal street light pole that may reasonably be expected to become energised from the electricity supply system if there is an insulation failure or contact with a conductor. The associated risk is the likelihood that a person might receive an electric shock through contact with exposed conductive parts of the light pole.

The relationship between hazard and risk is sometimes represented simply as:

$$\text{Risk} = \text{Hazard} \times \text{Exposure}$$

In the above relationship, the terms:

- \* Exposure would cover factors such as frequency of exposure to the hazard and probability of an incident occurring, and
- \* Hazard would include the possible consequences of an incident caused by such a hazard eg death, severe injury or property damage, or all of these factors.

### 2.2 The Risk Management process

There are five basic steps in the risk management process, through which an electricity entity can meet its obligation to ensure electrical safety.

- (i) **Identify the hazards** present in a particular work situation. If there is a regulation or ministerial notice about the hazards, you must implement those requirements.
- (ii) **Assess the risks** of injury or property damage that may result from the hazards. This step will help to determine the level of risk associated with the identified hazards and establish a priority list, based on risk levels. The desired outcome is a priority list for control measures.

(iii) **Decide on control measures** to eliminate the hazard or minimise the risk of injury or property damage. If there is a code of practice, you must either do what the code says or adopt another method of managing the exposure. The preferred hierarchy of control is:

- \* Eliminate the hazard
- \* Substitute a less hazardous material, process or piece of equipment
- \* Redesign equipment or work process
- \* Isolate the hazard
- \* Introduce administrative controls
- \* Use appropriate personal protective equipment.

You should always start at the top of the hierarchy. First, you should try to eliminate the hazard eg by turning off the power. If this measure fails or is not practical, only then should you move to the second level, and so on.

(iv) **Carry out the control measures;** and

(v) **Monitor and review** how effective the control measures are. It may be necessary to modify the control measure or the way it was implemented if the measures are not effective or if new problems arise.

The five steps of the risk management process are illustrated in Figure 1.

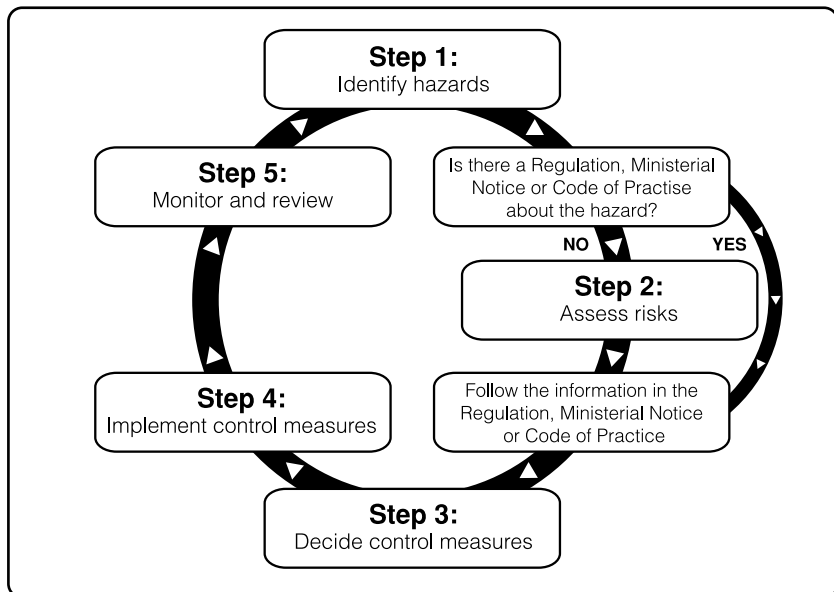


Figure 1: The Risk Management process

## 3. PROTECTIVE EARTHING

### 3.1 Scope

This section sets down the principles for the protective earthing of electrical equipment that forms part of the works of an electricity entity. The principles reflect established design principles used in the electricity supply industry.

Fundamental performance criteria are provided for ensuring permanent protective earthing systems are operated correctly. This is to ensure the correct operation of electrical protection systems so that exposed conductive parts of electrical equipment do not become energised to a potentially dangerous level.

### 3.2 Requirements under the *Electrical Safety Regulation 2002*

- (1) The works of an electricity entity must incorporate an earthing and protection system, to a recognised electricity supply industry standard capable of ensuring the following-
  - (a) reliable passage of fault current;
  - (b) reliable passage of single wire earth return load currents to ground or source;
  - (c) reliable operation of circuit protection devices;
  - (d) safe step, touch and transfer potentials for all electrical equipment;
  - (e) appropriate coordination with the earthing and protection systems of other electricity entities;
  - (f) protection against likely mechanical damage, inadvertent interference and chemical deterioration;
  - (g) mechanical stability and integrity of connections.
- (2) Without limiting subsection (1), the following specific requirements apply for the works of an electricity entity-
  - (a) to stop, as far as practicable, a person suffering electric shock-
    - (i) if the Multiple Earthed Neutral system of earthing is used, the neutral conductor of the system must be effectively earthed; and

- (ii) each non current carrying exposed conductive part of an electric line or generating plant must be effectively earthed;
  - (b) each non current carrying exposed conductive part of a substation must be effectively earthed;
  - (c) a system of earthing must be tested as soon as practicable after its installation to prove its effectiveness; and
  - (d) a high voltage electric line must be protected by a suitable fuse, circuit-breaker or equivalent device.
- (3) Earthing is not required under subsection (2)(a)(ii) or (b) in circumstances where the electricity entity, in accordance with a recognized practice in the electricity industry, considers that for safety reasons earthing is not appropriate.

### **Section 130 – Connection of high voltage circuit to earth**

- (1) Each distinct high voltage system included in the works of an electricity entity must be connected to earth by direct connection or through a resistance or a reactance.
- (2) All reasonable precautions must be taken to ensure that, for the circumstances in which the system is to operate, fuses or circuit-breakers in the system will operate during fault conditions.

### **Section 132 – Insulation of stay wire**

If a stay wire attached to a pole or structure supporting an overhead electric line forming part of the works of an electricity entity does not form part of an earthing system, the wire must be insulated to prevent, as far as practicable, any person suffering an electric shock.

### **Section 133 – Protection of earth conductors**

To prevent, as far as practicable, any person suffering an electric shock, earthing conductors installed on the outside of a pole or structure supporting an overhead electric line forming part of the works of an electricity entity must be, from ground level to a height of at least 2.4m

- (a) insulated or suitably covered by a nonconductive material; and
- (b) protected from mechanical damage.

### 3.3 Definitions

The terms used in this section are in addition to those defined in the *Electrical Safety Act* or the *Electrical Safety Regulation 2002*.

**CMEN** – Common Multiple Earthed Neutral.

**distribution system** – a system operating at a nominal voltage not exceeding 33kV.

**earth connection** – a connection to the general mass of earth by means of an earthing electrode or earthing electrodes electrically connected at a given location.

**earth resistance** – in relation to an earth connection, this means the resistance to the general mass of earth measured in ohms.

**earthing conductor** – a conductor connecting any portion of the earthing system to works required to be earthed, or to any other portion of the earthing system.

**earthing electrode** – a metal rod, tube, pipe, plate or other conductor buried in or driven into the ground and used for making a connection to the general mass of earth.

**earthing values** – values measured with an earth resistance tester.

**earthing system** – all conductors, piping, electrodes, clamps and other connections whereby conductors or other works are earthed.

**fault duration** – the time during which a fault current may flow before being cleared by the primary protection of a distribution or transmission system.

**frequented location** – any urban area associated with a city or town other than special locations.

**HV distribution centre** – any substation or generating station other than a low voltage distribution centre including high voltage switching stations;

**Insulated** – separated from adjoining conducting material by a non-conducting substance which provides resistance to the passage of current, or to disruptive discharges through or over the surface of the substance at the operating voltage, and to obviate danger of shock or injurious leakage of current;

**LV distribution centre** – any substation or generating station from which electricity is or can be supplied directly at low voltage to a distribution system or to a consumer’s electrical installation. A Single Wire Earth Return (SWER) isolating transformer substation and compact stand-alone distribution switchgear shall be classed as LV distribution centres for the purposes of this Code. An LV distribution centre may consist of one or more transformers on a pole, on or under the ground or in a building, or it may consist of one or more low voltage generating sets. A low voltage distribution centre may be located in a generating station or in a zone substation.

**MEN** – Multiple Earthed Neutral.

**exposed conductive parts** – includes electrical equipment that can be touched by the standard test finger as specified in AS/NZS 3100 and is not live, but can become live if basic insulation fails. The term includes reinforced concrete work or reinforced concrete parts but excludes minor fastenings, wood pole identification discs and street lights.

**prospective step voltage** – the voltage that may appear between any two points on the surface of the ground one metre apart. This voltage is defined as an open circuit voltage measured using a high impedance voltmeter.

**prospective touch voltage** – the voltage that may appear between any point of contact with exposed conductive parts within 2.4 metres of the ground, and within a radius of 1.0m at ground level. This voltage, too, is defined as an open circuit voltage measured using a high impedance voltmeter.

**remote location** – an area not defined as either special or frequented.

**special locations** – a location within a school’s grounds or within a children’s playground, or within a public swimming pool area, or at popular beach or water recreation area, or in a public thoroughfare within 100 metres of any of the above locations.

**step voltage** – the voltage drop caused by a current flowing through the body between both feet, in contact with the ground one metre apart.

**SWER** – Single Wire Earth Return.

**touch voltage** – the voltage drop caused by a current flowing through the body between both hands and both feet. In this instance, the hands are in contact with an earthed conductive part within 2.4 metres of the ground. The feet are within a radius of 1.0m at ground level.

**transmission system** – a system operating at a nominal voltage above 33kV and includes a sub transmission system.

### 3.4 Code of Practice requirements

#### 3.4.1 The Multiple Earthed Neutral (MEN) system

Where an MEN earthing system is used, the following conditions should be met:

- \* The neutral conductor should be earthed at or near each LV distribution centre; and
  - Where necessary, the neutral should be earthed at other points along the distribution system.
  - The earthing should be arranged so as to ensure that resistance of neutral to earth at any location does not exceed 10 ohms.

In the MEN system the high voltage and low voltage earthing systems should be kept separate.

The high voltage earthing system provides an earth return path for the high voltage system. The earthing system protects plant and equipment capable of being energised by the high voltage system eg surge arrester or transformer tank. This earth should always be insulated from the low voltage earth.

Where the LV distribution centre is in a remote location, permanently electrically isolated from other distribution centres and is rated at not more than 63 kVA, the limit of 10 ohms may be increased provided that:

- \* Where there are bare high voltage conductors above the low voltage conductors of an overhead electric line, the low voltage conductors must be insulated with 0.6/1 kV grade insulation; and
- \* the high voltage protection will clear any high voltage to low voltage fault in less than 0.2 seconds.

### **3.4.2 Earthing of LV distribution centres**

If an MEN system is used, the low voltage earthing system should be separate and distinct from the high voltage earthing system for the distribution centre. The earthing systems should be designed and installed to prevent any significant portion of the high voltage system voltage gradient being superimposed on the low voltage earthing system and as a result, transferred to the customer's electrical installation through the MEN system.

- \* When the two earthing systems are located where a person may make contact between the earthed exposed conductive parts or conductors connected to the earthing systems, adequate separation or insulation should be provided between the exposed conductive parts or conductors or both.

The following should be connected to the high voltage earthing system:

- \* transformer tank or tanks;
- \* HV surge protection devices;
- \* HV cable sheaths/screens/guards;
- \* exposed conductive parts of all other HV equipment.

The design and impedance to remote earth of the high voltage earthing system should be arranged so that:

- \* the HV protection system will operate in the event of a high voltage to exposed conductive parts fault; and
- \* the prospective touch voltage on uninsulated conductive parts up to 2.4 metres above ground level and prospective step voltages meet requirements set down in the prospective touch and step voltages section.

The low voltage earthing system should be bonded to:

- \* the neutral terminal of the distribution transformer, and
- \* any earth leads of low voltage surge protection devices at the distribution centre.

The impedance to remote earth of the low voltage earthing system should not exceed the value for the high voltage earthing system.

### **3.4.3 Exposed conductive parts within 2.4 metres above ground associated with high voltage in an MEN system**

Exposed conductive parts that may become energised from the electricity supply system if there is an insulation failure or contact with a conductor, should be:

- \* insulated; or
- \* earthed to a separate and distinct earthing system from the high voltage earthing system. The impedance to remote earth should allow the HV protection system to operate in the event of a high voltage to exposed conductive part fault; and
- \* be designed so that the prospective touch and step voltages meet the requirements set down in the prospective touch and step voltages section.

### **3.4.4 The Common Multiple Earthed Neutral (CMEN) system**

If an electricity entity uses a Common Multiple Earthed Neutral system, the low voltage neutral conductor, and the low voltage earthing system, should be connected to the high voltage earthing system. This requirement includes the earthing system of transformer stations, zone substations and at poles carrying exposed conductive parts associated with high voltages.

The CMEN system should only to be used for distribution voltages up to and including 33 kV and where the design limits prospective touch voltages – including within any part of the associated LV installations – to within curve A1 of Figure 2.

The resistance to ground of the LV neutral at any location should be no greater than 1.0 ohm.

### 3.4.5 Earthing at a distribution centre (CMEN)

If a CMEN system of earthing is used at a distribution centre the following should be connected to it:

- \* the transformer tank and any high voltage surge protection devices;
- \* the low voltage neutrals and earth leads of low voltage surge protection devices;
- \* any exposed conductive parts that may reasonably be expected to become energised from the electricity supply system if there is an insulation failure or contact with a conductor;
- \* a separate earthing system with a resistance to earth that will ensure the HV protection system operates in the event of a high voltage to exposed conductive parts fault and where the low voltage neutral may be disconnected.

### 3.4.6 Exposed conductive parts within 2.4 metres above ground associated with high voltage in a CMEN system

Exposed conductive parts that may reasonably be expected to become energised from the electricity supply system if there is an insulation failure or contact with a conductor, should be:

- \* insulated; or
- \* bonded to the CMEN system low voltage neutral.

### 3.4.7 The Single Wire Earth Return (SWER) system

If an electricity entity uses the single wire earth return earthing system, a separate high voltage earthing system and low voltage earthing system should be used. Thus, for each installation, there will be only a low voltage earth electrode system at the transformer and an earth electrode at the customer's premises earthing the low voltage neutral.

The high voltage and low voltage earthing systems should be separated to avoid any significant portion of the SWER earthing system voltage gradient being superimposed on the low voltage earthing system and as a result, transferred to the customer's electrical installation through the MEN system.

Where the two earthing systems are located so that personal contact may be made between the earthed exposed conductive parts or conductors connected to the earthing systems, adequate separation or insulation should be provided between the exposed conductive parts or conductors or both. This does not apply to spark gap devices fitted to protect the transformer against lightning damage.

The earthing of SWER distribution centres should be designed for continuous passage of electric current, in addition to protective earthing.

For a SWER distribution centre, two separate and distinct earthing systems should be provided:

- \* a SWER earthing system; and
- \* a low voltage earthing system.

The following exposed conductive parts should be connected to the SWER Earthing System:

- \* transformer tank or tanks;
- \* HV earth bushing;
- \* HV surge protection devices; and
- \* exposed metalwork of all other HV equipment.

The SWER earthing system should be designed so that:

- \* at least two earthing conductors are installed with maximum separation. The conductors should:
  - be connected to an inter connected earthing system that consists of at least three earthing electrodes not less than three metres apart; and
  - arranged so that in the event of one or two earthing conductors between two electrodes being severed, at least one earth path will remain.
- \* any joint in the SWER earthing conductors between the transformer terminals and the earth electrodes should not be disconnectable;
- \* at a SWER LV distribution centre, earthing conductors within 2.4m of the ground should be insulated with 0.6/1.1 kV grade insulation and must be mechanically protected; and
- \* the maximum voltage on the earth lead with respect to remote earth under operating conditions resulting in maximum continuous earth current, should not exceed 20 Volts.

The low voltage earthing system should be bonded to:

- \* the low voltage neutral terminal of the transformer, and
- \* any earth leads of low voltage surge protection devices at the distribution centre.

The design and impedance to remote earth of the low voltage earthing system should be arranged so that the MEN system complies as documented in the MEN section.

### **3.4.8 Exposed conductive parts within 2.4 metres above ground associated with high voltage in a SWER system**

Exposed conductive parts that may reasonably be expected to become energised from the electricity supply system if there is an insulation failure or contact with a conductor, should be insulated.

### **3.4.9 Earthing of high voltage distribution centres**

Earthing of exposed conductive parts of HV distribution centres including external metal fences should comply with the ESAA Substation Earthing Design Guide and the Institute of Electrical and Electronics Engineers Guide for Safety in AC Substation Grounding – IME Std. No. 80. Earthing of Works other than distribution centres.

### **3.4.10 Exposed conductive parts within 2.4 metres above ground associated with high voltage transmission systems**

Exposed conductive parts that may reasonably be expected to become energised from the electricity transmission system in the event of failure of insulation or contact with a conductor, should be designed so that the prospective touch and step voltages do not exceed the allowable prospective touch and step voltages.

### **3.4.11 Exposed conductive parts within 2.4 metres above ground associated with low voltage only**

Exposed conductive parts that may reasonably be expected to become energised from the electricity supply system in the event of failure of insulation or contact with a conductor, should be either insulated or bonded to the low voltage neutral of the system.

### **3.4.12 Induced voltage on the sheath of underground electric lines**

Cable sheaths or screens should be earthed to ensure that the prospective touch voltages that may appear on any accessible exposed conductive parts of the underground electric line for both load and fault current conditions, meet the requirements set down in the prospective touch and step voltages section.

### **3.4.13 Exposed conductive parts higher than 2.4 metres above ground**

Non-current carrying exposed conductive parts located 2.4m or higher above ground and not exposed to personal contact need not be earthed. If these parts are associated with high voltage or low voltage works or both and are required by the electricity entity to be earthed, these parts should be earthed in accordance with sections on high voltage in an MEN system, CMEN system or low voltage only systems.

## **3.5 Earthing Conductors**

### **3.5.1 Minimum size of earthing conductors**

Earthing conductors should have sufficient cross-sectional area and mechanical strength to be capable of carrying, without sustaining damage or deterioration, any currents that may reasonably be expected.

### **3.5.2 Materials for earthing conductors**

The material for earthing conductors should be suitable for site conditions.

### 3.5.3 Mechanical protection of earthing conductors

In locations controlled by an electricity entity and where a suitable enclosure prevents unauthorised access, the following apply:

- \* the entity should effectively protect an earthing conductor against mechanical damage to a height of 2.4m above ground level; and
- \* where the earthing conductor is installed below ground level, it should be buried to a minimum depth of 0.5m. Where necessary, this can be done by installing the earthing conductor in a channel chased in the rock and covered with concrete at least 50mm thick.

### 3.5.4 Materials for earthing electrodes

Earthing electrodes should be made from metals that will not be materially affected by any corrosive or other adverse influences.

### 3.5.5 Test links

If test links are inserted in earthing conductors connected to earthing electrodes, the test links should be arranged so that the opening of any one link does not interfere with earth connections, other than the one under test.

Links should not be installed in a SWER earthing system.

### 3.5.6 Earth fault currents

Earthing electrodes should be capable of carrying, without sustaining damage, any earth fault currents that may reasonably be expected.

## 3.6 Prospective touch and step voltages

### 3.6.1 Prospective touch voltages – special locations

Lines operating at voltages less than or equal to 66kV should comply with the requirements of curve A1 of Figure 2.

Lines operating at voltages greater than 66 kV should comply with the requirements of curve A2 of Figure 2.

### 3.6.2 Prospective touch voltages – frequented locations

Lines operating at voltages less than or equal to 66kV should comply with the requirements of curve B1 of Figure 2.

Lines operating at voltages greater than 66 kV should comply with the requirements of curve B2 of Figure 2.

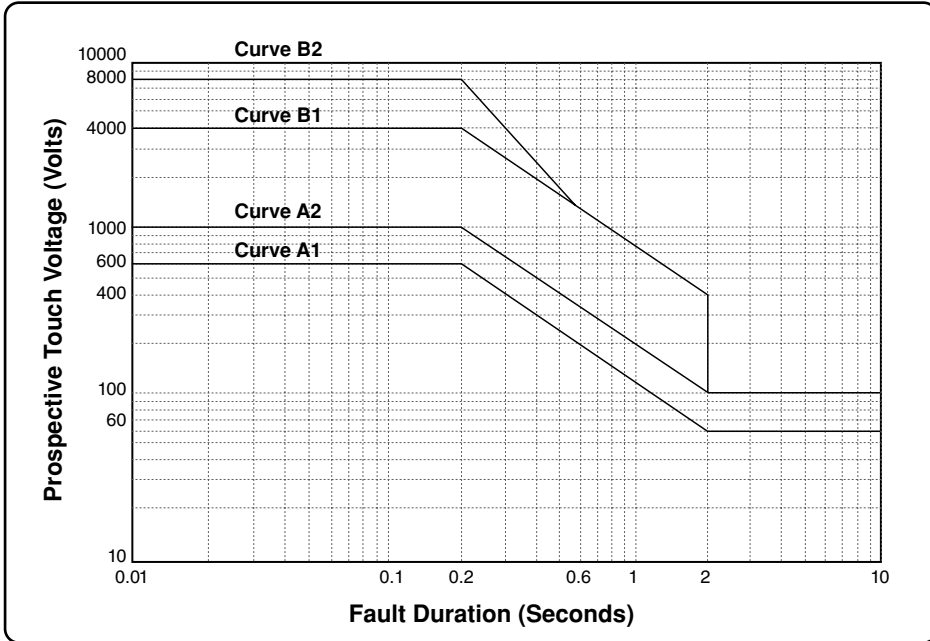


Figure 2: Touch Voltage versus Fault Duration

### 3.6.3 Remote locations

Aside from ensuring positive primary protection operation, it is not necessary to make specific provisions for limiting prospective touch and step voltages on exposed B2 conductive parts. However, in the case of pole-mounted equipment that may be operated from the ground in remote locations, you should consider limiting step and touch voltages to the levels recommended for frequented locations.

To protect workers working near exposed conductive parts in remote locations, special operating procedures such as temporary earth rods or portable equipotential mats and gloves may be used.

### **3.6.4 Prospective step voltages**

Prospective step voltages should not exceed twice the value of the prospective touch voltage determined for the corresponding location as outlined in the sections, Prospective touch voltages – special locations and Prospective touch voltages – frequented locations.

### **3.6.5 Testing and maintenance of earthing systems**

All earthing systems should be tested periodically to ensure the earthing system integrity.

Adequate records of all earthing system tests should be maintained.

## **3.7 References**

ESAA Earthing Guides for Transmission Lines, Substations, Distribution Systems and Large Interconnected Systems;

Institute of Electrical and Electronics Engineers Guide for Safety in AC Substation Grounding – IEEE Std. No. 80;

Institute of Electrical and Electronics Engineers Recommended Guide for Measuring Ground Resistance and Potential Gradients in the Earth - IEEE Std. No. 81.

## 4. DESIGN AND INSTALLATION OF UNDERGROUND ELECTRIC CABLE SYSTEMS

### 4.1 Scope and application

This section sets down the principles for the mechanical and electrical design of underground electric lines, other than those operating at voltages normally not exceeding 50 volts alternating current or 120 volts ripple-free direct current.

The requirements have been based on recognised industry standards. They represent the minimum standards necessary to meet an electricity entity's obligations.

Unless otherwise expressly stated, this section does not apply to:

- \* any underground earthing conductor not specifically associated with an underground electric line or with an underground control cable;
- \* underground electric lines or underground control cables fully or partly constructed in places owned only by an electricity entity and where a substation enclosure prevents unauthorised access;
- \* submarine cables; or
- \* fibre optic cables.

### 4.2 Definitions

In this section, the terms used have the meanings respectively assigned to them by the Act or the Regulation:

**EMF** – Electro Magnetic Field.

**IEC Standard** – a standard rule, code or specification of the International Electrotechnical Commission.

**roadway** – that part of a road intended for use by vehicles but not including a driveway crossing a footpath.

**electricity footpath allocation** – the corridor in the footpath allocated by the local authority for installation of electric cables and plant.

**trenchless construction** – the technique of installing cables and ducting by means of directional drilling and systems with minimum excavation.

**underground cable** – one or more insulated conductors encased in a protective sheath or enclosure and forming part of an underground electric circuit.

**underground control cable** – an auxiliary cable with one or more insulated conductors encased in a protective sheath or enclosure and forming part of a measuring, control, protection or communication circuit.

### 4.3 Compliance with Standards

Underground electric cable systems should be designed in accordance with an appropriate Australian Standard. Where there is no appropriate Australian Standard, an appropriate IEC Standard should be used.

### 4.4 Selection of cables

#### 4.4.1 General

Cables used in underground cable systems should comply with an appropriate Australian Standard.

In addition, consideration should be given to the following:

- \* safety;
- \* environmental conditions;
- \* life cycle assessment;
- \* insect or vermin attack;
- \* vibration;
- \* ultraviolet degradation;
- \* economic, security and reliability factors;
- \* forces incurred during installation;
- \* forces incurred during the service life of the cable;
- \* corrosion protection of armouring and sheathing;

#### 4.4.2 Conductors

When selecting the cross-sectional area of the conductors of an underground electric cable, keep in mind the:

- \* prospective load;
- \* voltage drop;
- \* fault currents;
- \* fault clearing times;
- \* proximity of other heat sources, e.g. cables;
- \* thermal properties of the surrounding environment.

#### 4.4.3 High voltage cables

High voltage underground cables should have integral metallic conducting screens or sheathing or both.

#### 4.4.4 Low voltage cables

All conductors including the neutral should be insulated to the full voltage rating of the cable. Bare neutral conductors should not be used.

#### 4.4.5 Neutral connections

The connections between neutral conductors should be designed and installed to ensure the connections maintain the required conductivity during the service life of conductors.

#### 4.4.6 Route selection

Basic factors to be considered during the selection of an optimum cable route are set out in ESAA C(b)2.

In addition, consideration should be given to:

- \* EMF mitigation;
- \* Environmental impact issues.

## 4.5 Installation

### 4.5.1 General

Underground electric cables and underground control cables should be installed having regard to system reliability, ease of future maintenance and safety. Consideration should also be given to minimising damage to underground assets.

Basic factors to be considered during the installation of underground cables are set out in ESAA C(b)2.

### 4.5.2 Cable depths

The depth of cover for underground electric cables and underground control cables should not be less than:

For open trench construction:

- \* 750 mm below the surface of a roadway for any cable installed under a roadway; and
- \* 600 mm below the finished ground surface for cables installed in other locations.

Where physical obstructions such as other services make it impossible to achieve these depths, additional mechanical protection should be provided by means of a minimum cover of 100 mm of 20 MPa concrete or equivalent. Any additional mechanical protection should be marked with the words *electric cable* or similar along its length.

For trenchless construction:

- \* 900 mm below the finished ground surface.

This clause does not apply to that part of an underground cable or an underground control cable entering or leaving the ground vertically or fixed above the ground to a secure structure, so long as adequate mechanical protection is provided.

### 4.5.3 Laying of cables

The technique used for installing underground cables should ensure that damage to the cables is negligible. Consideration should be given to:

- \* maximum hauling tensions;
- \* minimum bending and setting radii;
- \* cable side wall pressures; and
- \* cable abrasion avoidance.

### 4.5.4 Separation of cables

When determining minimum separation from telecommunication plant in a shared trench, refer to the Standards Australia manual CJC4-2000 Coordination of Power and Telecommunications.

Consult the authority concerned about separation from other services sharing the trench, keeping in mind:

- \* employee and public safety;
- \* potential cable damage due to failure of other services; and
- \* future access for repairs/maintenance.

## 4.6 Protection of cables

### 4.6.1 Identification of underground cables

The presence of buried underground electric cables and underground control cables should be identified. Accepted methods of identification include:

Where the depth of cover is between 600mm and 900mm:

- \* laying a strip of bright orange polyvinyl chloride or polyethylene or similar marker tape above the cable. The tape is to have the words electric cable or similar, boldly printed on the upper side continuously along its length, and
- \* where appropriate, using on-ground or above ground marker systems.

The position of marker tape, should provide effective warning to anyone engaged in manual or machine excavation.

Where the depth of cover is 900mm or greater, it is not a requirement to place cable protection covers or marker tape above the cable or conduits. However, the location of cables should be marked with permanent on-ground or above ground cable marker systems.

#### **4.6.2 Protection general**

An electricity entity should have procedures in place to protect people and prevent damage to underground cables during excavation near underground cables.

These procedures should include but are not limited to:

- \* maintenance of 'as installed' records of underground cables by an electricity entity;
- \* provision at the worksite of 'as installed' underground cable records to anyone concerned with planning, organising and supervising excavation work;
- \* the use of records and other locating methods to positively identify the position of underground cables; and
- \* exercising care during subsequent excavation.

#### **4.6.3 Protection – mechanical**

In addition to the principles outlined in the section, *Identification of underground cables* and *protection general*, mechanical protection should be provided to minimise the risk of injury to anyone digging by hand near underground cables by:

- \* providing the minimum requirement for mechanical protection of underground cables in accordance with the table opposite.

Cable Location	Minimum Requirement
<p>Where the underground electric cables and underground control cables are installed with a depth of cover between 600mm and 900mm.</p>	<p>Install the cable in a suitable conduit for application under roads, and LD Class electrical conduit for application in the electricity footpath allocation. For application outside the electricity footpath allocation LD Class electrical conduit with a polymeric cable protection cover complying with AS4702 not less than 75mm above the cable or, polyethylene orange coloured pressure pipe of minimum rating PN10 for PE80 Class pipe complying with AS/NZS4130.</p> <p>OR</p> <p>A polymeric cable protection cover complying with AS4702, not less than 75mm above the cable.</p> <p>OR</p> <p>Approved bricks manufactured especially for the protection of electric cables.</p> <p>Assess the risk for each location type to determine the method of mechanical protection.</p>
<p>Where the depth of cover for any underground electric cables and underground control cables is 900mm or greater.</p>	<p>No additional mechanical protection is required.</p>

**NOTE:** Polymeric cable protection cover and approved bricks provide superior protection. These should be considered for locations where cables would not normally be found eg parklands or unsealed walkway easements. Also consider using armoured or metallic sheathed cable buried according to cable depths in this section.

For cable circuits requiring high security or where the risk of excavation is high, increased protection should be provided by:

- \* using a combination of the above provisions for mechanical protection; or
- \* the use of a heavier duty conduit; or
- \* encasing the cables in concrete.

Where there is a risk of cable or duct damage by excavating plant or vibration, increased protection should be provided by:

- \* laying the cable at a greater depth; or
- \* selecting a less exposed cable route.

#### **4.6.4 Protection – above ground**

Looping, linking and servicing connections made above ground should be housed in pillars or pits that must:

- \* be externally marked to include the words *electric*, *electrical*, or *electricity*;
- \* be secured using a special tool or key;
- \* when enclosing switchgear, be constructed to prevent water from accumulating, unless the switchgear is specifically designed for operation when submerged;
- \* be designed so that an object (defined as a standard test finger AS/NZS 3100 :2002) cannot be inserted into the interior and come into contact with or within arcing distance of live parts; and
- \* Be installed in places where vehicles are not likely to damage them.

Where an underground electric cable or underground control cable is located between the laying depth prescribed in this section and a distance of 2.4m above ground, the cable must be suitably protected so that the cable will withstand, without undue damage, any impact that might normally be expected at that location.

#### **4.6.5 Protective earthing of cables**

When earthing single core cables, consider the special bonding arrangements used to minimise sheath losses and induced sheath voltages.

#### **4.6.6 Records**

Records should be current for all cable installations using maps, plans or computer databases. When preparing a record system, consider the following details:

- \* alignments;
- \* cable depths;
- \* number of cables;

- \* cable details;
- \* specialised backfill;
- \* reduced levels;
- \* direct buried or ducted;
- \* service history;
- \* position of joints;
- \* date of installation.

## 4.7 References

### 4.7.1 Cable Selection

AS 1026	Electric cables – Impregnated paper insulated – Working voltages up to and including 33 kV.
AS 1049	Telecommunication cables – Insulation, sheath and jacket.
AS 1429.1	Electric cables – Polymeric insulated – For working voltages 1.9/3.3 (3.6) kV up to and including 19/33 (36) kV.
AS/NZS 1429.2	Electric cables – Polymeric insulated – For working voltages above 19/33 (36) kV up to and including 76/132 (145) kV.
AS/NZS 3116	Approval and test specification – Electric cables – Elastomer insulated – For working voltages up to and including 0.6/1 kV.
AS/NZS 3155	Approval and test specification – Electric cables – Neutral screened – For working voltages up to and including 0.6/1 kV.
AS/NZS 3198	Approval and test specification – Electric cables – XLPE insulated – For working voltages up to and including 0.6/1 kV
AS 4026	Electric cables – For underground residential distribution systems.

### 4.7.2 Route Selection

ESAA C(b)2.	Guide to the Installation of Cables Underground
CJC4 – 2000	Coordination of Power and Telecommunications Cable Installation
ESAA C(b)2.	Guide to the Installation of Cables Underground
ESAA D (b)26	Guide for Working on Cables and Auxiliary Equipment under Induced Voltage Conditions and Transferred Earth Potentials.
AS/NZS 2053	Conduits and fittings for electrical installations
AS 4702	Polymeric cable Protection Covers

## 5. MAINTENANCE OF SUPPORTING STRUCTURES FOR LINES

### 5.1 Scope & application

This section sets down the principles and minimum requirements for maintaining the supporting structures for overhead lines.

An electricity entity should have a maintenance system that achieves a minimum three-year moving average reliability against the incidence of failure of 99.99 per cent a year.

Special consideration should be given to poles in areas of higher risk, such as cities and towns.

This section does not apply to safe access for work on poles. For this information, see the Code of Practice for Electrical Work under the *Electrical Safety Act 2002*.

### 5.2 Definitions

In this section, the terms used shall have the meanings respectively assigned to them by the *Electrical Safety Act and Regulation 2002* and unless the contrary intention appears, the following definitions apply.

**pole** – an overhead line or street light support structure, excluding attachments eg x-arms.

**fully supported pole** – a pole in which resultant pole-top forces are countered by changed tensions in conductors or stay wires or both (other than service lines). This support ensures little or no bending moment at ground line.

**serviceable pole** – a pole in service which, at the time of inspection and assessment, is considered capable of bearing its design load with the relevant Factor of Safety (FOS). The FOS for wood poles is equal to or greater than 2. The FOS for other structures as per C(b)1.

**suspect pole** – a pole in service which, at the time of inspection, is considered to require further assessment to determine whether or not it is serviceable.

**unserviceable pole** – a pole in service which, at the time of inspection and assessment, is considered incapable of bearing its design load with the relevant Factor of Safety (FOS). The FOS for wood poles is equal to or greater than 2. The FOS for other structures as per C(b)1.

**failed pole** – a pole which, due to loss of strength has broken off or become incapable of standing without mechanical means of support other than permanent reinstatement. The following exclusions apply:

- \* weather more severe than design conditions allowed for at that location e.g. lightning, severe storms and so on;
- \* impact loads contacting poles or their attachments, e.g. vehicles, falling trees or wind borne objects;
- \* unforeseeable changes in ground conditions eg flooding or earthworks;
- \* bush fires and grassfires; and
- \* vandalism.

**reinstated pole** – a pole in which the original foundation has been supplemented or replaced by a structurally effective support system.

**proof testing** – an assessment in which the strength of a pole is verified by validated application of a mechanical load to simulate the design load multiplied by the factor of safety.

**non-destructive evaluation** – an assessment in which the strength of a pole is verified by validated non-destructive techniques.

**factor of safety** – the ratio of assessed pole bending strength to its design bending strength.

**design load** – the calculated load imposed upon a pole under the loading conditions (calculated maximum service load) adopted by the electricity entity.

Refer to this section for the reliability objective applying to pole failure.

### 5.3 Serviceability determination

Provisions of this code should be accompanied by responsibly developed and documented procedures for inspecting, assessing, marking and maintaining poles and structures that support overhead lines. Such procedures should be supported by appropriate work practices, and competency training and assessment.

The serviceability of a pole shall be determined by its:

- \* above ground condition;
- \* ground line and below condition; and
- \* strength in its "as is" condition.

An electricity entity should develop a periodic maintenance program to deliver the reliability level set out at the beginning of this section. This program should include an inspection system to verify structural integrity, both above and below ground.

Where appropriate for the supporting structure, the inspection should also determine the bending strength of a pole for comparison with its design load and an applied factor of safety.

Pole strength may be determined by:

- \* measuring physical dimensions and calculation; or
- \* proof testing; or
- \* non-destructive evaluation.

Where resultant pole top forces result in a bending moment at ground line of equal to or close to zero eg a fully supported pole situation, the following requirements should be satisfied:

- \* the conductors and attachments should be capable of continuing to support the pole top loading conditions; and
- \* a minimum pole tip loading should be adopted to ensure the groundline shear strength of the pole is adequate.

Poles should be classified as either serviceable, suspect or unserviceable.

### 5.3.1 Frequency of inspection

An electricity entity's inspection program should ensure the entity meets its safety obligations. Each pole should be inspected at intervals deemed appropriate by the entity. The intervals may be based on documented knowledge of the durability rating, preservation type, inspection procedures, age, performance of the poles, fungal decay, termite hazard and so on.

In the absence of documented knowledge of pole performance, poles should be inspected at least every five years.

## 5.4 Marking of poles

### 5.4.1 General

An electricity entity should mark poles assessed as suspect or unserviceable. All markings should be about 1.5 m above ground line and on the side of the pole to which the pole identification record is fixed eg pole number. Markings should be in white or yellow paint and bold enough to be easily identifiable, even when visibility is poor. Any suspect or unserviceable poles shall be appropriately marked before the inspector leaves the site.

### 5.4.2 Marking scheme

Serviceable poles	- No marking required
Suspect Poles	- A single diagonal stripe " / "
Unserviceable poles	- A single " X "

### 5.4.3 Removal of markings

Where it is necessary to remove the suspect or unserviceable mark, the painted cross or diagonal slash should, on the authority of a responsible officer, be either over-painted with a dark coloured paint or removed.

#### **5.4.4 Resultant action and timeframes**

Once a pole’s serviceability has been determined, the following action and timeframes should apply:

- Serviceable pole – no further action;
- Suspect pole – assess pole within three months;
- Unserviceable pole – replace or reinstate pole within six months.

When a pole, at the time of inspection or assessment, is considered to present a high risk of injury or damage to property, immediate remedial action should be taken.

#### **5.4.5 Pole records**

An electricity entity should develop a reference system for supporting structures, to establish inspection and maintenance records.

Pole records should enable an electricity entity to:

- \* demonstrate that the entity’s pole reliability objective is achieved;
- \* compile statistics to determine the service performance of poles;
- \* determine future policies from a better knowledge of pole performance, maintenance and preservation methods;
- \* demonstrate that this section’s requirements have been complied with; and
- \* programme the inspection and maintenance of poles.

### **5.5 Reference**

ESAA HB C(b)1 Guidelines for Design and Maintenance of Overhead Distribution and Transmission Lines.



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